ERRATA[1]
for the third and fourth printings of
Doppler Radar and Weather Observations, Second Edition-1993
Richard J. Doviak and Dusan S. Zrnic'
Academic Press, Inc., San Diego, 562 pp.
ISBN 0_12_221422_6.

Page	Para.	Line	Remarks: Paragraph 0 is any paragraph started on a previous page that carries over to the current page. A sequence of dots is used to indicate a logical continuation to existing words in the textbook (e.g., see errata on pp.14, 76, paragraph 3 on p. 108, etc.)
xix		θ	modify definition to read: "is the zenith angle (Fig. 3.1); also the angle from the axis of a circularly symmetric beam (p. 34); also potential energy
14	2	2	change to read: "…index $n = c/v$ with height (or, because the relative permeability μ_r of air is unity, on the change of relative permittivity, $\varepsilon_r = \varepsilon/\varepsilon_o = n^2$, with height).
17	1	2-6	line 2, change "T=300 K" to "T=290 K"; line 4, change this equation to read: $N \approx 0.268 \times (10^3 + 1.66 \times 10^2) \approx 312$; and line 6 change "1.000300" to "1.000312".
30	2	9	replace the italicized "o" from the first entry of the word "oscillator" with a regular "o", but italicize the "o" in the second entry of the word "$o$scillator"
	3	7	delete the parenthetical phrase
34	Eqs.3.2		replace D with D_a
35	1	9	at the end of the last sentence add: with origin at the scatterer.
	2	10	the equation on this line should read:

$$\sigma_b = \sigma_{bm}\left(1 - \sin^2 \psi / \sin^2 \theta\right)^2 \cos^4[(\pi/2)\cos\theta] / \sin^4 \theta$$

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[1] Updates to the errata are periodically posted on NSSL's website at nssl.noaa.gov. Click the links to Scientific Publications, Recent Books, and Errata 2nd edition, 3rd and 4th printings. Also posted are Supplements that clarify or extend the book text.

Eq.(3.6) and on the line after this equation, change "K_m" to "K_w"

36 0 7 delete "$|K_m|^2 \equiv$"

9 change the end of this line to read: "Ice water has a $|K_w|^2 \equiv$"

40 Eq.(3.14b) replace subscript "m" with "w"

47 Table 3.1 change title to read: "The *nex*t generation *rad*ar, NEXRAD (WSR-88D), Specifications"
change "Beam width" to "Beamwidth"
change footnote *b* to read: "Initially the first several radars transmitted circularly polarized waves, but now all transmit linearly polarized waves".
Change footnote *c* to read: "Transmitted power, antenna gain, and receiver noise power are referenced to the antenna port, and a 3 dB filter bandwidth of 0.63 MHZ is assumed.

61 Eq.(3.40b) place $\pm$ before v_a

0 14 last line change to "velocity limits (Chapter 7)."

68 3 8 change to read as: "or expected power $E[P(\tau_s)]$."

68-69 4 1,10,12 change "$\overline{P}(\tau_s)$" on these three lines to "$E[P(\tau_s)]$"

71 Eqs.(4.4a,b) insert ($1/\sqrt{2}$) in front of the sum sign in each of these equations

3 6 replace "p. 418" with "p. 498".

Eq. (4.6) delete the first "2"

72 0 4 change $\overline{P}(\tau_s)$ to $E[P(\tau_s)]$

2 1 change $\overline{P}(\tau_s)$ to $E[P(\tau_s)]$

3 remove footnote

73 Eq. (4.11) change "$\overline{P}(r_0)$" to "$E[P(r_0)]$".

74-75 Eqs. (4.12), (4.14), (4.16): change "$\overline{P}(r_0)$" to "$E[P(r_0)]$".

75 1 6 change to "$G(0) =1$"

2	18	change " $\overline{P}(r_0)$ " to " $E[P(\mathbf{r}_0)]$ ".

76 Fig.4.5   change second sentence in caption to read: "The broad arrow indicates sliding of...."

82 Eq.(4.31)   delete the subscript "w" on Z

Eq.(4.32)   delete the subscript "w" on Z

Eq. (4.34)   change " $P(\bar{r}_0)$ " to " $E[P(\mathbf{r}_0)]$ ".

Eq. (4.35)   change " $\overline{P}(\text{mw})$ " to " $E[P(\text{mw})]$ "

1   9   should read: ".. is the *reflectivity factor* of spheres."

83 Eq.(4.38)   subscript " τ " should be the same size as in Eq.(4.37).

84 Eq. (4.39)   change " $\overline{P}(r_0)$ " to " $E[P(\mathbf{r}_0)]$ ".

85 Problem 4.1   change " $\overline{P}$ " to " $E[P]$ " in two places.

108 1   1   change "stationary" to "steady"

1   11   change " $d\overline{P}$ " to " $E[dP]$ ".

Eq. (5.42)   change " $d\overline{P}(v)$ " to " $E[dP(v)]$

15   change " $\overline{P}(\mathbf{r}_0,v)$ " to" $E[\Delta P(\mathbf{r}_0,v)]$ "

Eq.(5.43)   change " $\overline{P}(\mathbf{r}_0,v)$ " to" $E[\Delta P(\mathbf{r}_0,v)]$ "

3   2-3   change to read: ".....by new ones having different spatial configurations, *the estimates* $\hat{S}(\mathbf{r}_o,v)$ *of* ..."

109 Eq.(5.45)   change " $\overline{P}(\mathbf{r}_0)$ " to " $E[P(\mathbf{r}_0)]$ "

4   1   add subscript "I" to $\bar{\eta}$ so it reads as " $\bar{\eta}_I(\mathbf{r}_0)$ "

Eq.(5.46a)   add subscript "I" to $\bar{\eta}$ on the left side of this equation.

Change footnote "4" to read: "...denotes a weighted spatial average."

| 113 | 1 | 1-4 | change to read: "Assume scatterer velocity is the sum of steady v_s and turbulent $v_t(\mathbf{r},t)$ wind components. Each contributes to the width of the power spectrum (even uniform wind contributes to the width because radial velocities vary across V_6; steady wind also brings new...." |
| | 2, 3 | 10, 3 | delete the sentences beginning on line 10 in paragraph 2 with "Furthermore, we assume..." and ending in paragraph 3, line 3 with "...scatterer's axis of symmetry)." |

Eq. (5.59a)   change to:

$$R(mT_s) = E[V^*(\tau_s,0)V(\tau_s,mT_s)]$$

$$= E\left[\sum_i \sum_k F_i^*(0)A_i^*(0)F_k(mT_s)A_k(mT_s)\exp\{j(\phi_i - \phi_k - 4\pi v_k mT_s/\lambda\}\right] \qquad (5.59a)$$

$$= \sum_k E[A_k^*(0)A_k(mT_s)F_k^*(0)F_k(mT_s)\exp\{-j4\pi v_k mT_s/\lambda\}]$$

Following this equation retype the text up to and including Eq. (5.59c) as follows:

The expectation in Eq. (5.59a) includes the ensemble of statistically stationary and homogeneous turbulent velocity fields. The expectations of the off-diagonal terms of the double sum are zero because the phases $(\varphi_i - \varphi_k)$ are uniformly distributed across 2π; thus the double sum reduces to a single one. To simplify further analysis, assume that the weighted scatterer's cross section $F_k A_k$ is independent of v_k, and that F_k does not change appreciably [i.e., $F_k(0) \approx F_k(mT_s)$] while the scatterer moves during the time mT_s. Furthermore, assume A_k varies randomly in time (i.e., a hydrometeor may oscillate or change its orientation relative to the electric field). Thus Eq. (5.59a) reduces to

$$R(mT_s) = \sum_k R_k(mT_s)|F_k|^2 \, E[\exp\{-j4\pi v_k mT_s/\lambda\}] \qquad (5.59b)$$

where

$$R_k(mT_s) = E[A_k^*(0)A_k(mT_s)]$$

Because $R(0)$ is proportional to the expected power $E[P]$, and because

$$E[P(\mathbf{r}_0)] = \sum_k \sigma_{bk} I(\mathbf{r}_0, \mathbf{r}_k) \qquad (5.59c)$$

| 114 | 2 | 2-4 | modify to read: "...mechanisms in Eq. (5.59b) act through product terms. Furthermore, the kth scatterer's radial velocity v_k can be expressed as the sum of the velocities due to steady and turbulent winds that move the scatterer from one range position..." |

4

6-9   delete these lines and replace with:

"…Eq. (5.59b), the velocities $v_s(r)$ and $v_t(r, t)$ associated with steady and turbulent winds can each be placed into separate exponential functions that multiply one another. Thus the expectation of the product can be expressed by the product of the exponential containing $v_s(r)$ and the expectation of the exponential function containing $v_t(r, t)$; these exponential functions are correlation functions. The Fourier transform of $R(mT_s)$, giving the composite spectrum $S(f)$, can then be expressed as a convolution of the spectra associated with each of the three correlation functions. There are other de-correlating mechanisms (e.g., differential terminal velocities, antenna motion, etc.,) that increase the number of correlation functions and spectra to be convolved. It is shown that, …."

115   Eq. (5.60)   add a hat above "S" to read as "$\hat{S}$" in the three places it appears.

3   1   "R" in "R_k" should be italicized to read "R_k"

9   change "Eq. (5.59a)" to "Eq. (5.59b)"

14   Change these lines and Eqs. (5.64) to read: "Because the correlation coefficient can be related to the normalized power spectrum $S_n(f)$ by using Eq. (5.19), and because the Doppler shift $f = -2v/\lambda$, $\rho(mT_s)$ can be expressed as

$$\rho(mT_s) = \int_{-\lambda/4T_s}^{\lambda/4T_s} \frac{2}{\lambda} E[\hat{S}_n^{(f)}(-2v/\lambda)]e^{-j4\pi vmT_s/\lambda}\, dv$$

$$= \int_{-v_a}^{v_a} E[\hat{S}_n(v)]e^{-j4\pi vmT_s/\lambda}\, dv, \tag{5.64}$$

116   0   1-4   change these lines to read: where $S_n^{(f)}(-2v/\lambda)$ is the normalized power spectrum in the frequency domain folded about zero, $S_n(v)$ is the normalized power spectrum in the Doppler velocity domain, and the two power spectra are related as

$$S(v) = \frac{2}{\lambda} S^{(f)}(-2v/\lambda). \tag{5.65}$$

By equating Eq. (5.63) to Eq. (5.64), and assuming all power is confined within the Nyquist limits, $\pm v_a$, it can be concluded that

$$p(v) = E[\hat{S}_n(v)]\ . \tag{5.66}$$

5

1		1-3	change to read: "Thus, for homogeneous turbulence, at least homogeneous throughout the resolution volume V_6, the *expected* normalized power spectrum is equal to the velocity probability distribution. Moreover, it is independent of reflectivity and the angular and range weighting functions.
1		3-7	Delete the last two sentences beginning with "Although, in deriving…."
117	2	4-7	Modify these lines to read: "where the terms are due to shear of v_s along the three spherical coordinates at $\mathbf{r}_0$. In this coordinate system (5.70) automatically includes…"
		9	change to read: "the so-called beam-broadening term;…."
117-118; 3			Replace the text in this paragraph up to and including Eq. (5.75) with:

"Spherical coordinate shears of v_s can be directly measured with the radar and it is natural to express σ_s^2 in terms of these shears. If the resolution volume V_6 dimensions are much smaller than its range r_0, and angular and radial shears are uniform, v_s within V_6 can be expressed as

$$v_s - v_0 \approx k_\varphi r_0 \sin\theta_0 (\varphi - \varphi_0) + k_\theta r_0 (\theta - \theta_0) + k_r (r - r_0) \qquad (5.71)$$

provided $\theta_1 \ll 1$ (radian) and $\theta_0 \gg \theta_1$, where

$$k_\varphi \equiv \frac{1}{r_o \sin\theta_0}\frac{\partial v_s}{\partial\varphi}, \quad k_\theta \equiv \frac{1}{r_o}\frac{\partial v_s}{\partial\theta}, \quad k_r \equiv \frac{\partial v_s}{\partial r} \qquad (5.72)$$

are angular and radial shears of v_s. Angular shears, defined as the velocity change per differential arc *length* (e.g., $r_0\sin\theta_0 d\varphi$), are present even if Cartesian shears are non-existent, and they are functions of $\mathbf{r}_0$. For example, if wind is uniform (i.e., has constant Cartesian components u_0, v_0, w_0),

$$\frac{\partial v_s}{\partial\phi} = (u_0\cos\phi_0 - v_0\sin\phi_0)\sin\theta_0; \quad \frac{\partial v_s}{\partial\theta} = w_0\sin\theta_0 - (u_0\sin\phi_0 + v_0\cos\phi_0)\cos\theta_0; \quad k_r = 0 \quad. \qquad (5.73)$$

If reflectivity is uniform and the weighting function is product separable and symmetric about $\mathbf{r}_0$, substitution of Eq. (5.71) into Eq. (5.51) produces

$$\sigma_s^2(\mathbf{r}_0) = \sigma_{s\theta}^2 + \sigma_{s\phi}^2 + \sigma_{sr}^2 = k_\theta^2 r_0^2 \sigma_\theta^2 + k_\phi^2 r_0^2 \sigma_\phi^2(\theta_0)\sin^2\theta_0 + k_r^2\sigma_r^2. \qquad (5.74)$$

Because lines of constant ϕ converge at the vertical, the second central

moment $\sigma_\phi^2(\theta_0)$ of the two-way power pattern is $\sigma_\phi^2(\theta_0) = \sigma_\phi^2(0)/\sin^2\theta_0$, where $\sigma_\phi(0)$ is the intrinsic azimuthal beamwidth; σ_r^2 is the second central moment of $|W(r)|^2$. For circularly symmetric Gaussian patterns,

$$\sigma_\theta = \frac{\theta_1}{4\sqrt{\ln 2}} \; ; \quad \sigma_\phi(\theta_0) = \frac{\theta_1}{4\sqrt{\ln 2}}\frac{1}{\sin\theta_0} \qquad (5.75)$$

125	1	1	replace "average" with "expected"
	Eq. (6.5)		append to this equation the footnote: "In chapter 5 ρ is the complex correlation coefficient. Henceforth it represents the magnitude of this complex function."
	4	5	remove the overbar on P, S, and N
126	0	1	change to read: "power estimate $\hat{P}$ is reduced......variance of the P_k.."
	3	2-4	the second sentence, modified to read, "The P_k values of meteorological interest...meeting this large dynamic range requirement", should be moved to the end of the paragraph 1
		5	change "$\overline{P}$" to "S".
127	0	1-2	remove the overbar on P in the three places
	3	1	remove the overbar on Q
		8	delete the citation "(Papoulis, 1965)"
128	1	8	change "unambiguous" to "Nyquist"
	2	4-7	rewrite the second and third sentences after Eq. (6.12) as: "The variance of S estimated from M samples is calculated using the distribution given by Eq. (4.7) in which $S \equiv P$ (this gives, in Eq. (6.10), $\sigma_Q^2 = S^2$), and calculating M_I from Eq. (6.12). Thus the standard deviation of an M-sample signal power estimate is $S/\sqrt{M_I}$."
	3	1-2	change to read "To estimate S in presence of receiver noise, we need to subtract....."
		4-9	remove overbars on S and N
129	0	5-6	change last sentence to read: "....then the number of independent samples

can be determined using an analysis similar to.....”

130	Table 6.1		add above **"Reflectivity factor calculator"** the new entry "**Sampling rate",** and in the right column on the same line insert "0.6 MHz". Under "**Reflectivity factor calculator**", "Range increment" should be "0.25 km" and not "1 or 2 km". But insert as the final entry under "**Reflectivity factor calculator**" the entry "Range interval Δr", and on the same line insert "1 or 2 km" in the right column.

136 footnote change to read:
"To avoid occurrence of negative $\hat{S}$, only the sum in Eq. (6.28) is used but it is multiplied with $S\hat{N}R/(S\hat{N}R+1)$ "

137 2 1 delete "($\sigma_{vn} > 1/2\pi$)"

155 3 3 in section 6.8.5 line 3, change "Because" to "If"

160 2 6 change "unambiguous velocity " to "Nyquist velocity"

171 0 3 T_s should be T_2

173 0 1 change to read: "…velocity interval $\pm v_m$ for this…."

Eq. (7.6b) place $\pm$ before v_m

3 9-10 this should read: "…the desired unambiguous velocity interval. An unambiguous velocity interval $v_m = \ldots$"

11 change "unambiguous" to "Nyquist"

182 Eq.(7.12) $W_i W_{i+1}$ should be $W_i W_{i+l}$

197 1 1 "though" should be "through"

2 4 "Fig.3.3" should be "Fig.3.2"

200 Fig.7.28 Note the dashed lines are incorrectly drawn; they should extend from -26 dB at $\pm 2^o$ to -38dB at $\pm 10^o$, and then the constant level should be at -42 dB.

201 0 2 "Norma" should be "Norman"

222 Eq. (8.18) the differential "dD" on the left side of Eq.(8.18) must be moved to the end of this equation.

| 228 | 1 | 4 | change Z_w to Z_e |

Eq.(8.24) this equation should read as:

$$Z_i = (|K_w|^2 / |K_i|^2)Z_e \qquad (8.24)$$

2　　6　　change to: "..to estimate the equivalent rainfall rate R_s (mm/hr) from the..."

　　　7　　delete "with $Z_w = Z_e$"

232　0　　10-11　change to: "...a microwave (i.e., $\lambda = 0.84$ cm) path, confirmed...."

234　Eq.(8.30)　right bracket "}" should be matched in size to left bracket "{"

248　Eq.(8.57)　parenthesis ")" needs to be placed to the right of the term "(b/a"

249　Eq.8.58　$\cos^2 \delta$ should be $\sin^2 \delta$; replace k_o with k; p_v and p_h should be replaced with p_a and p_b respectively

　　Eq.8.59a,b　change the subscripts "h" to "b", and "v" to "a"

　　2　　9　　change to read: "p_a and p_b are the drop's susceptibility in generating dipole moments along its axis of symmetry and in the plane perpendicular to it respectively, and e its eccentricity,"

　　　12-13　rewrite as: "...symmetry axis, and Ψ is the apparent canting angle (i.e., the angle between the electric field direction for "vertically" polarized waves (**v** in Fig.8.15) and the projection of the axis of symmetry onto the plane of polarization. The forward scattering........"

　　　17　　modify to read: "...$f_h = k^2 p_b$, and $f_v = k^2 [(p_a-p_b)\sin^2\delta + p_b]$ (Oguchi, ...)"

　　3　　4-5　Rewrite as: "Hence from Eqs.(8.58) an oblate drop has, for horizontal propagation and an apparent canting angle equal to zero, the following cross sections for h and v polarizations:"

268 Fig. 8.29　LDR$_{hv}$ on the ordinate axis should be LDR$_{vh}$

　　0　　1,4　change LDR$_{hv}$ to LDR$_{vh}$ at the two places it appears in this paragraph.

269 Fig. 8.30　In the caption, change LDR$_{hv}$ to LDR$_{vh}$ at the two places it appears.

277　0　　16　change "23000" to "230,000"

289	2	3	delete the sentence beginning with "In this chapter overbars…."
298	Fig.9.4a,b		here and elsewhere in the text, remove periods in time abbreviations (i.e., should be: "CST", not C.S.T.")
390	0	1	change to read "along the path ℓ of the aircraft, and $S_{ij}(K_\ell)$ is the Fourier transform of $R_{ij}(\ell)$. In contrast...."
393	1	11	the subscripts on $R_{11}(0)$ should be changed to $R_{ll}(0)$; (i.e., so that it is the same as the subscripts on the second "D " in line 19).
	Eq. (10.33)		place subscript l on C so that it reads C_l.
394	0	1	change to read: "where C_l^2 is a dimensionless parameter with a value of about 2."
	Eq.(10.37)		change to read:

$$R_{ii}(\rho, \tau_1 = 0) = R(0)[1 - (\rho/\rho_{oi})^{2/3}] \qquad (10.37)$$

398	1	12	change to read: "…of the weighting function I_n, and $\Phi_v(\mathbf{K})$ is the spatial spectrum of point radial velocities."
		17	change to read: "…antenna power pattern under the condition, $\theta_e = \pi/2 - \theta_0 \ll 1$, and…."
404	4	7	place an over bar on the subscript "u" in the next to last equation
412	2,3	2,1	delete the word "linear" in these two lines.
	2	5	change "polynomial surface" to "polynomial model"
		7	change "surface" to "model"
419	Fig. 10.18		the "-5/3" dashed line drawn on this figure needs to have a -5/3 slope. Furthermore, remove the negative sign on "s" in the units (i.e., m^3/s^{-2}) on the ordinate scale; this should read (m^3/s^2).
445	1	6	delete "time dependence of the"
453	1	10	delete "(s)" from "scatterer(s)"; subscript "c" in $\rho_{c,||}$ should be replaced with subscript "B" to read $\rho_{B,||}$
		12	a missing subscript on $\rho_{,\perp}$ should be subscript "B" so the term reads: $\rho_{B,\perp}$

Eqs. (11.105, &106) the symbols $\|\&\perp$ should also be subscripts, along with "B", on the symbol "ρ" to read " $\rho_{B,\|}$ " and " $\rho_{B,\perp}$ ".

454　0　6 change "blob" and "blobs" to "Bragg scatterer" and "Bragg scatterers"

Fig.11.11 caption should be changed to read: "........, a receiver, and an elemental scattering volume dV_c."

456 Eq. (11.115) bold "r" in the factor $W(\mathbf{r})$ needs to be unbolded

Fig. 11.12 add a unit vector $\mathbf{a}_o$ drawn from the origin "$\mathbf{O}$" along the line "r_0".

458　2　4 make a footnote after $\sqrt{2}$ to read: z′ is the projection of r′ onto the z axis; not to be confused with z′ in Fig.11.12 which is the vertical of the rotated coordinate system used in section 11.5.4.

459　Eq.(11.125) delete the subscript "c" in this equation, as well as that attached to ρ_{ch} in the second line following Eq.(11.125) so that it reads " ρ_h ".

460　1　4-9 delete the third to fifth sentences in this paragraph and replace with the following:
Condition (11.124) is more restrictive than (11.106); if (11.124) is violated the Fresnel term is required to account for the quadratic phase distribution *across the scattering volume*, whereas (11.106) imposes phase uniformity *across the Bragg scatterer*; this latter condition is more easily satisfied the farther the scatterers are in the far field (also see comments at the end of section 11.5.3).

464 Fig. 11.14 caption: the first citation is incorrect. It should read: "(data are from Röttger et al., 1981)". Furthermore, delete the last parenthetical expression: "(Reprinted with permission from ….)."

468　2　11 change "(11.109)" to "11.104"

478　0　7 Change to read:
"...the gain g. Then g, now the directional gain (Section 3.1.2), is related..."

493　1 delete the last sentence and make the following changes:

1) change lines 2 and 3 to read: "... $C_n^2 = 10^{-18}\,m^{-2/3}$ (Fig.11.17), the maximum altitude to which wind can be measured is computed from

11

Eq.(11.152) to be about 4.5 km."

2) change lines 4 and 5 to read: "…that velocity estimates are made with SNR = -19.2 dB (from Eq.11.153 for T_s = 3.13x10^{-3} s), and that σ_v = 0.5m s^{-1}, SD(v) = 1 m s^{-1}, and a system temperature is about 200 K (section 11.6.3)."

2 1-4   change to read: "Assuming that velocities could be estimated at SNRs as low as -35dB (May and Strauch, 1989), the WSR-88D could provide profiles of winds with an accuracy of about 1 m s^{-1} within the entire troposphere if C_n^2 values…"

8   change "14" to "12"

9   change "able to measure" to "capable of measuring"

SUPPLEMENTS

The following supplements are provided at the indicated places to clarify and/or extend the text of "Doppler Radar and Weather Observations", Second Edition-1993.

Page	Para.	Line	Remarks: Paragraph 0 is any paragraph started on a previous page that carries over to the current page.
33	1	4	change to read: …and often its intensity (i.e., power density) versus…
34	0		Note that the one-way radiation pattern of the WSR-88D radar (the network radar used by the Weather Service in the USA) is well approximated with

$$ f^2(\theta) = \left(\frac{48.2 J_3(u)}{u^3} + \frac{0.32 J_1(u)}{u} \right)^2 / (1.16)^2. $$

This agrees, down to about the -20 dB level, to within 2 dB of the pattern measured for NSSL's research WSR-88D at a wavelength of 0.111m. The pattern given by this equation is slightly broader (i.e., the 3 dB beamwidth calculates to about 1° whereas the measured width is about 0.93^o). This analytical expression is that obtained if the reflector's aperture is illuminated with a power density $[1-4(\rho/D_a)^2]^4$ on a uniform illumination level producing at the reflector's edge a power density 17.2 dB below the peak. The 1st and 2nd sidelobe levels, calculated from the above expression, are 34.2 and 48.4 dB below the peak lobe at about 1.7^o and 2.5^o respectively; sidelobes beyond 3° have relatively uniform levels that range from 56.3 (at 3°) to 62 dB below the peak lobe at 10°. Measured sidelobe levels (see Fig. 7.28), however, can be anywhere from a few dB to about 18 dB larger (the largest difference is at about 3°). The increased measured levels are due to scatter and blockage from the feed and its supporting spars, distortions in the surface of the reflector, and scatter from objects (i.e., trees, buildings, etc.) on the antenna measurement range. Sidelobe levels are even larger (e.g., 25 dB above the theoretical level at 3°) along measurement lines perpendicular to the feed supporting spars. But these enhanced levels, due to the blockage of radiation by the spars, are confined to relatively narrow angular sectors.

| | 2 | 6 | If the shape of the radiation pattern of a beam, not necessarily circularly symmetric, is well approximated by the product of two Gaussian functions, the maximum directional gain is |

$$ g'_t = \frac{1}{\sigma_\phi \sigma_\theta}, $$

13

where σ_ϕ^2 and σ_θ^2 , assumed to be much smaller than 1 rad^2, are the second central moments of the two-way pattern expressed in normal form. The two-way pattern is the product of the transmitted radiation pattern and the receiving antenna's field of view pattern. Typically the same antenna is used for both functions, and thus the two-way pattern is $f^4(\theta)f^4(\phi)$. For the circularly symmetric pattern of the WSR-88D, the two-way pattern is $f^4(\theta) = \exp\{-\theta^2/2\sigma_\theta^2\}$. In terms of the one-way 3-dB pattern width θ_1, $\sigma_\theta = \theta_1/4\sqrt{\ln 2}$.

35 1   There are several definitions of cross sections. For example, $\sigma_d = \dfrac{S_r}{S_i}r^2$

is the *differential scatter cross section*; that is, it is the cross section *per unit* solid angle. Integration of $\sigma(\theta',\phi')$ over 4π steradians gives the *total scatter cross section* (see section 3.3).

36 0 2   Insert at the end of the first sentence: "It can be shown, using formulas presented in Section 8.5.2.4, that Eq. (3.6) has practical validity only if drops have an equivalent spherical diameter D_e less than 2 mm. Drops having D_e larger than 2 mm have backscatter cross sections differences larger than about 0.5 dB for horizontally and vertically polarized waves (i.e., $\sigma_h > 1.1\sigma_v$)."

38 0 1-2   change to read: "…flows in the forward or backward directions.

   1 4   add at the end of this paragraph: "Furthermore, Probert-Jones (1984) demonstrated that internal resonances in electrically large low-loss spheres can generate greatly enhanced scatter in both the forward and backward directions.

42 Fig. 3.5   Caption: Because there is considerable confusion concerning the use of the unit dBZ, and because some writers use dBz for the decibel unit of reflectivity factor Z, we present the following comment:

   The logarithm unit decibel, abbreviated dB, is related to the less used unit "bel", named in honor of Alexander Graham Bell (1847-1922). The dB has been accepted widely as a "unit" (e.g., Reference Data for Radio Engineers, 5th Edition, Howard W. Sams, publisher, division of ITT, p.3-3). Appendages to dB have been *accepted in the engineering field* to refer the dB unit to a reference level of the parameter being measured; e.g., dBm is the decibel unit for $10 \log_{10} P$ where P is the power referenced to 1 milliwatt (e.g., Reference Data for Radio Engineers, 5th Edition, op. cit., p.3-3). The parameter dBZ *has been accepted by the AMS* as the symbol for the "unit" decibel of reflectivity factor referred to 1 mm^{6}m^{-3} (Glossary of Meteorology, 2nd Edition, 2000, American Meteorological Society).

44 3 4   Blake has more recently published (1986, in "Radar range performance

14

analysis", 2nd ed., ARTECH House, Norwood, MA.) new values of attenuation in gases. For example, at $\lambda = 10$ cm, $r = 200$ km, $\theta_e = 0^o$, the two way loss is about 0.3 dB larger than that given in Fig.3.6.

56   Eq. (3.34)   If the beam is passing through clouds and storms, Eq. (3.34) should be replaced by

$$T_s' = \left(1 - \frac{1}{\ell_c}\right)(1 - \chi + \chi\eta_r)T_c + \frac{1 - \chi}{\ell_c}T_s + \chi(1 - \eta_r)T_g + \frac{\chi\eta_r}{\ell_c}T_s$$

where ℓ_c and T_c are the cloud's attenuation and temperature.

57   Fig. 3.11   For completeness, the ordinate should be labeled "Sky noise temperature T_s (K)"

71   2, 3   An explanation for the $\sqrt{2}$ factors in Eqs. (4.4) and (4.6) and how power is related to σ^2 might be helpful. Because a lossless receiver is assumed, the sum of powers in the I and Q channels must equal the power at the input to the receiver (i.e., the synchronous detectors in Fig. 3.1). Because we have assumed the amplitude of the echo voltage at the receiver's input is A (e.g., Eq. (2.2b)), the amplitude of the signal in the I and Q channels must be $A/\sqrt{2}$. Furthermore, we can determine from Eq. (4.5) that the rms values of I and Q voltages equals σ (i.e., $I_{rms} = Q_{rms} = \sigma$). Thus the average power in each of the channels is σ^2, and the sum of the average powers in these two channels is $2\,\sigma^2$ which equals the expected power E[P] at the input to the receivers. The constants of proportionality (i.e., impedances) that relate voltage to power are assumed the same at all points in the receiver (e.g., at inputs to the I and Q channels).

109   Eq. (5.47)   change $\bar{v}(\mathbf{r}_0)$ to E[$v(\mathbf{r}_0)$] in this equation and on the last line of this page because the overbar designates a spatial average, and Eq. (5.47) is simply the mean Doppler velocity. Eq. (5.48) shows that E[$v(\mathbf{r}_0)$] is equal to $\bar{v}(\mathbf{r}_0)$ as stated on the last two lines of this page.

110   Eq. (5.48)   change $\bar{v}(\mathbf{r}_0)$ to E[$v(\mathbf{r}_0)$], and "$= \bar{v}(\mathbf{r}_0)$" at the end of this equation. Then add after this equation: "Eq. (5.48) shows that the first moment of the Doppler spectrum equals the weighted spatial average of expected velocities."

At the end of section 5.2, add the following paragraph:
In this section we assumed scatterers follow exactly the air motion. But usually scatterers are hydrometeors that fall in air, have different fall speeds because of their different sizes, and change orientation, and vibrate (if they are liquid). These hydrometeor characteristics broaden the

15

Doppler spectrum associated with the velocity field increasing $\sigma_v^2(\vec{r}_o)$ obtained from Eq. (5.51).

118   0   after Eq. (5.75): It should be noted that as $\theta_0 \rightarrow 0$, the angular shears in Eq. (5.74) should be replaced by k_θ along the two principal axes of the beam pattern. For example, if the beam is circular symmetric and $\theta_0 = 0$, $\sigma_s^2 = r_o^2 \sigma_\theta^2 [k_\theta^2(\phi = 0) + k_\theta^2(\phi = \pi/2)] + (\sigma_r k_r)^2$.

After Eq. (5.76): It should be noted that if the receiver bandwidth B_6 is much larger than the reciprocal of the pulse width τ, $\sigma_r^2 = \dfrac{1}{12}\left(\dfrac{c\tau}{2}\right)^2$.

128, Eq.(6.13):   this equation is valid when signal power is much stronger than noise power. The following text gives the standard deviation of the Logarithm of Z(dBZ) estimates as a function of Signal-to-Noise ratio and could replace paragraph 3 on p.128.

To estimate Z in presence of receiver noise, we need to subtract receiver noise power N from the signal plus noise power estimate $\hat{P}$. Thus the reflectivity estimate is

$\hat{Z} = \alpha\hat{S} = \alpha(\hat{P} - N)$ where $\hat{P}$ is a uniformly weighted M sample average estimate of the power P at the output of the square law receiver (as in the WSR-88D), N is the receiver noise power, and α is a constant calculated from the radar equation. Because N is usually measured during calibration, many more samples are used to obtain its estimate. Therefore its variance is negligibly small, and the noise power estimate can safely be replaced with its expected value N. Z is usually expressed in decibel units; that is, $\hat{Z}(dBZ) = 10\log_{10}\hat{Z} = 10\log_{10}(\alpha\hat{S})$ where $\hat{Z}$ is expressed in units of $mm^6\,m^{-3}$. The error in decibel units is now derived. Let $\hat{S}$, the M sample estimate of signal power, be expressed as $\hat{S} = S + \delta S$ where δS is the displacement of $\hat{S}$ from S. Thus

$$\hat{Z}(dBZ) = 10\log_{10}(\alpha S) + 10\log_{10}\left(1 + \frac{\delta S}{S}\right) = Z + \delta Z(dBZ) \qquad (6.13a)$$

For sufficiently larger M, $\delta S / S$ is small compared to 1, and hence the second term can be expanded in a Taylor series. Retaining the dominant term of the series, the estimated reflectivity is well approximated by

$$\hat{Z}(dBZ) \approx Z + 4.34\left(\frac{\hat{S}}{S} - 1\right). \qquad (6.13b)$$

Because the first term and the constant 4.34 are not random, the standard error in the estimate is simply $S.D.[\hat{Z}(dBZ)] = 4.34\,S.D.[\hat{S}/S]$. Because $\hat{S} = \hat{P} - N$ where N is a known constant (for a correctly calibrated radar), $S.D.[\hat{S}] = S.D.[\hat{P}] = P/\sqrt{M_I} = (S + N)/\sqrt{M_I}$, where M_I is the number of independent signal plus noise power samples. Hence

$$S.D.[\hat{Z}(dBZ)] = \frac{4.34(S + N)}{S\sqrt{M_I}} \qquad (6.13c)$$

The number of independent samples M_I that are contained in the M sample set, can be calculated from (6.12) in which $\rho_s(mT_s)$ is replaced by $\rho_{s+n}(mT_s)$ the magnitude of the correlation coefficient of the signal plus noise samples.

Using (6.4), the correlation of signal plus noise for a Gaussian shaped signal spectrum and a white noise spectrum, normalizing it by $S + N$ to obtain the correlation *coefficient* of the input signal plus noise power estimates, the correlation coefficient at the output of the square law receiver, can be written as

$$\rho_{s+n}(mT_s) = \left(\frac{S}{S + N} \exp\{-2(\sigma_{vn}\pi m)^2\} + \frac{N}{S + N}\delta_m \right)^2 \qquad (6.13d)$$

Under the condition that $\sigma_{vn} \gg M^{-1}$, (i.e., the spacing between spectral lines is much smaller than the width of the spectrum), the sum in (6.12) can be replaced by an integral. Furthermore, if M is large so that $\rho_{s+n}(mT_s)$ is negligibly small at MT_s, the limits on the integral can be extended to infinity. Evaluation of this integral under these conditions yields

$$M_I = \frac{\left(1 + \dfrac{S}{N}\right)^2 M}{1 + 2\dfrac{S}{N} + \dfrac{(S/N)^2}{2\sigma_{vn}\sqrt{\pi}}} \qquad (6.13e)$$

The formula for calculating the standard error in estimating $Z(dBZ)$ as a function of S/N is obtained by substituting (6.13e) into (6.13c) yielding

$$S.D.[\hat{Z}(dBZ)] = \frac{4.34}{\sqrt{M}} \frac{N}{S}\left(1 + 2\frac{S}{N} + \frac{(S/N)^2}{2\sigma_{vn}\sqrt{\pi}}\right)^{1/2} dB \qquad (6.13f)$$

136	4	1-5	The form of Eq.(6.29) was first presented by Rummler (1968). *But this form does not follow directly from Eq.(6.27) as in stated in the sentences preceding Eq.(6.29).* Thus it would be more proper to change these lines to read:

"If spectra are not Gaussian, Rummler (1968) has derived an estimator valid for small spectrum widths (i.e., $\sigma_{vn} \ll 1$). This estimator is

$$(6.29)$$

At large widths Eq. (6.29) has an asymptotic ($M \rightarrow \infty$) negative bias which causes an underestimate of the true spectrum width (Zrnić, 1977b), whereas .... spectrum is Gaussian)"

Added Reference:

Rummler, W. D. (1968), Introduction of a New Estimator for Velocity Spectral Parameters. *Technical Memorandum, April 3, 1968.* Bell Laboratories, Whippany, New Jersey 07981.

| 255 | 1 | 2 | Recent data from a disdrometer show as much as a factor of 3 error |

| 391 | 0 | 2 | it should be noted that the correlation scale ρ_0 is not the same as the integral scale ρ_I which is defined as |

$$\rho_I = \int_{0}^{\infty} \frac{R(\rho)}{R(0)} d\rho$$

For the correlation function given by Eq. (10.19), ρ_0 is related to ρ_I as

$$\rho_I = \frac{\Gamma(v + 0.5)\Gamma(0.5)}{\Gamma(v)} \rho_0$$

| 398 | | | Section 10.2.1: we introduce the parameter $\mathbf{M}(\mathbf{K})$ in Eq.(10.46) but define it later in Eq.(10.46). We should place Eq.(10.48), but label it (10.46), before Eq.(10.46) that now become Eq.(10.47). Other adjustments should be made to correct equation numbers; these should be few. |

| 403 | 1 | 6 | For a fuller explanation of the steps in Section 10.2.2, and using notation consistent with that used earlier in the text, we offer the following revision of section 10.2.2: |

In this section we define the relationship between the variance of radial velocities at a point and the expected spectrum width measured by radar (Rogers and Tripp, 1964). Let the variance of the radial velocity $v(r, t)$ at a point be σ_p^2. This variance is the sum of the variance at all velocity scales and is defined by the equation,

$$\sigma_p^2(r) = E[v^2(r,t)] - E^2[v(r,t)] \qquad (10.55)$$

18

where $E[x]$ indicates an expectation, or an average over an ensemble of velocity fields, all having the same statistical properties. Assume that steady wind is not present (or that it can be determined and was removed), the radar beam is fixed, hydrometeors do not oscillate or wobble and are perfect tracers of the wind (i.e., terminal velocities and drop inertia can be ignored). In this case, turbulence is the only mechanism contributing to spectral broadening, and its radial velocity component is a random variable having a zero mean (i.e., $E[v(\boldsymbol{r}, t)] = 0$).

The second central moment, σ_v^2, of the Doppler spectrum associated with turbulence can be obtained from Eq. (5.51). Although Eq. (5.51) was derived under the assumption that $v(\boldsymbol{r}, t)$ is steady, this equation can be applied to the time varying wind produced by turbulence. But then σ_v^2 would be a time varying quantity because $v(\boldsymbol{r}, t)$ is now a time dependent variable. Thus, from Eq. (5.51) replacing $\sigma_v^2 \rightarrow \sigma_t^2$ for pure turbulence, we obtain,

$$\overline{\sigma_t^2(\boldsymbol{r},t)} = \overline{\left[v(\boldsymbol{r},t) - \overline{v(\boldsymbol{r},t)}\right]^2} = \overline{v^2(\boldsymbol{r},t)} - \overline{v(\boldsymbol{r},t)}^2 , \qquad (10.56)$$

where $\overline{\sigma_t^2(\boldsymbol{r},t)}$ is the expected radar-measured instantaneous second central moment of the Doppler spectrum associated with turbulence. The *overbar* denotes a spatial average weighted by the normalized function $H_n(\boldsymbol{r}_0,\boldsymbol{r})$ where

$$H_n(\boldsymbol{r}_0,\boldsymbol{r}) = \frac{I(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})}{\iiint I(\boldsymbol{r}_0,\boldsymbol{r})\eta(\boldsymbol{r})dV} ,$$

is a combination of reflectivity and antenna pattern weights. Note that $\sigma_t^2(\boldsymbol{r},t)$ is the *expected* instantaneous second central moment of the Doppler spectrum for signals from an elemental scattering volume at $\boldsymbol{r}$. In this case, however, the expectation is over ensembles of scatterers that have the same velocity field but have slightly different (i.e., on the order of a quarter of a wavelength) spatial locations, whereas the expectation in Eq. (10.55) is understood to be taken over ensembles of velocity fields. That ensemble averages can also be made over various configurations of scatterers has been shown by Doviak and Zrnic (1993, p.108). That is, if $v(\boldsymbol{r}, t)$ is the actual velocity field at 't', and $\overline{v(\boldsymbol{r},t)}$ is the $H_n(\mathbf{r}_0,\mathbf{r})$ weighted spatial average, expectations can be made, at least in theory, over ensembles of scatterer locations.

For example, an estimate of the "instantaneous" value $\overline{v(r,t)}$ can be obtained from a pair of weather echoes about a millisecond apart (for 10 cm wavelength radars); during this short interval the turbulent velocity field can be considered to be frozen. If, for the same velocity field, a different configuration of scatterers is created, another independent estimate of $\overline{v(r,t)}$ can be calculated. In this case the ensemble is the various configurations of scatterer locations for the same $v(r,t)$. Thus $\overline{v(r,t)}$ is defined as an expected instantaneous value wherein the expectation is made over various configurations of scatterers. It follows that $\overline{v(r,t)}$ is a random variable. Similar arguments and conclusions apply as well to $\overline{\sigma_t^2(r,t)}$. Thus, even if turbulence were statistically stationary, $\overline{\sigma_t^2(r,t)}$ would be a function of time. Usually we are not interested in the time dependence of $\overline{\sigma_t^2(r,t)}$, but in its statistical properties such as its mean or expected value, $E\left[\overline{\sigma_t^2(r,t)}\right]$, its auto-correlation, etc. We shall show how $E\left[\overline{\sigma_t^2(r,t)}\right]$ is related to the energy density E of turbulence.

The variance of the spatially weighted Doppler (i.e., radial) velocity $\overline{v(r,t)}$ is, by definition, given by

$$\text{var}\left[\overline{v(r,t)}\right] \equiv E\left[\overline{v(r,t)}^2\right] - E^2\left[\overline{v(r,t)}\right] \equiv \sigma_{\overline{v}}^2 \tag{10.57a}$$

or, because $E\left[\overline{v(r,t)}\right] = 0$,

$$\sigma_{\overline{v}}^2 = E\left[\overline{v(r,t)}^2\right], \tag{10.57b}$$

where *the expectation is over ensembles of velocity fields*, or over time. Even if turbulence is statistically stationary, $\overline{v(r,t)}$ is still a time varying quantity, although its variance $\sigma_{\overline{v}}^2$ is not.

It should also be noted that $\sigma_{\overline{v}}^2$ does not include the variance associated with the statistical uncertainty in the radar *estimates* of $\overline{v(r,t)}$ (nor does $\overline{\sigma_t^2(r,t)}$ include statistical uncertainties associated with radar estimation). That is, in addition to the variance of $\overline{v(r,t)}$ due to the time changing velocity field, we have additional variance associated with the random location of scatterers (i.e., the time dependence of $\overline{v(r,t)}$ differs from the time dependence of the $\overline{v(r,t)}$ estimates). For example, even if $v(r, t)$ was a constant independent of time, and therefore $\overline{v(r,t)}$ would be a constant, the radar estimates of $\overline{v(r,t)}$ would be random due to the fact that scatterers can have different locations for the same velocity field; each configuration of scatterers would produce a different weather signal sample from which $\overline{v(r,t)}$ is estimated.

To illustrate, assume a constant wind that carries scatterers perpendicularly across

20

all azimuths. In this case $v(r,t) = v(r) = 0$, and $\overline{v(r)} = $ constant $= c = 0$. Nevertheless, estimates $\hat{c}$ of $\overline{v(r)}$ are time varying and random because $\overline{v(r)}$ is estimated from weather signals which are randomly varying; this is so because the scatterers' configuration within V_6 is continually changing. That is, although $\overline{v(r)} = 0$, the Inphase, I, and Quadrature phase, Q, components of the weather signal are still Gaussian distributed random variables as shown in Fig. 4.4a. Because the mean Doppler velocity is zero, the time sequence of I, Q samples will randomly shift in the I, Q plane, but there would be no mean rotation about the origin (contrary to that suggested by Fig. 4.4a). The shifts of the I, Q samples are relatively smooth if the sample time spacing T_s is short compared to the correlation time τ_c of the weather signals.   The correlation time τ_c is not necessarily equal to the correlation time of the velocity field. The velocity estimates, calculated from the sequence of I, Q samples, form a sequence of random variables. The velocity estimates would be uncorrelated if the dwell time (i.e., the data collection time to make a velocity estimate) is longer than τ_c, and the samples do not overlap. The infinite time average of these velocity estimates would be equal to 0, as would the ensemble average over the infinite configurations of scatterers. These arguments, applied to the radar estimates of $\overline{v(r,t)}$, can also be applied to show that the expected value of the radar estimates of $\overline{\sigma_t^2(r,t)}$ equals $\overline{\sigma_t^2(r,t)}$.

By taking the ensemble (ensemble of velocity fields) average of Eq. (10.56), substituting Eq. (10.57b) into it, we obtain, after commuting ensemble and spatial averages (i.e., $E\left[\overline{v^2(r,t)}\right] \equiv \overline{E[v^2(r,t)]}$),

$$E\left[\overline{\sigma_t^2(r,t)}\right] + \sigma_{\bar{v}}^2 = \overline{E[v^2(r,t)]} \tag{10.58a}$$

The weighted spatial average of $E[v^2(r,t)]$ is, by definition,

$$\overline{E[v^2(r,t)]} = \int_V E[v^2(r,t)]H_n(r_0,r)dV \tag{10.58b}$$

If turbulence is homogeneous (i.e., $E[v^2(r,t)] = E[v^2(t)]$) over the region where the weighting functions contribute significantly (i.e., turbulence is locally homogeneous), Eq. (10.58b) shows that $\overline{E[v^2(r,t)]} = E[v^2(t)]$. Substituting this latter relation into Eq. (10.58a), and using Eq. (10.55), we obtain

$$E_r = \frac{1}{2}\gamma E[v^2(t)] = \frac{1}{2}\gamma \sigma_p^2 = \frac{\gamma}{2}\left\{ E\left[\overline{\sigma_t^2(r,t)}\right] + \sigma_{\bar{v}}^2 \right\} \tag{10.59}$$

where E_r is the radial component of turbulent energy density at a *point*, and γ is the air mass density. If turbulence is isotropic, the total turbulence energy density $E = 3\,E_r$.

Eq. (10.59) shows that the energy density of turbulence can be calculated from the sum of the expected value of the second moment of the Doppler spectrum associated with turbulence, $E\left[\overline{\sigma_t^2(\boldsymbol{r},t)}\right]$, and the variance, $\sigma_{\bar{v}}^2 = E\left[\overline{v(\boldsymbol{r},t)}^2\right]$, of the mean Doppler velocities. For stationary and/or globally homogeneous turbulence, the expectations can be obtained from averages over time and/or space (i.e., at different $\boldsymbol{r}_0$ locations). The variance $\sigma_{\bar{v}}^2$ does not include the variance associated with the statistical uncertainty of the estimates of $\overline{v(\boldsymbol{r},t)}$ due to processing a finite number of weather signal samples.

The relation Eq. (10.59), between the radial component of the turbulent energy density at a *point* and the second central moment of turbulence spectra, requires turbulence to be *locally* homogeneous although not isotropic. Therefore, the point under discussion is, in reality, a collection of points over the entire resolution volume wherein turbulence is assumed to have the same statistical properties at each point.

In addition to being proportional to turbulent kinetic energy, the variances $E\left[\overline{\sigma_t^2(\boldsymbol{r},t)}\right]$ and $\sigma_{\bar{v}}^2$ have relative magnitudes that depend on how turbulent energy is partitioned between sub resolution volume scales and scales larger than the resolution volume. By combining these two variances, there is no filtering of the turbulent energy.

| 439 | 0 | 9 | because section 11.4.1 is titled "Bragg scatter", it is appropriate to define and use this term in this section. Therefore change this line to read: ".. to the scattered signal (i.e., Bragg scatter) occurs if.." |

443 section 11.4.3   to differentiate the commonly known Bragg scatter associated with steady or deterministic perturbations from that Bragg scatter associated with random perturbations, we introduce the term "Stochastic Bragg Scatter" by replacing the second sentence of this section with:

"Perturbations in atmospheric refractive index are caused by temperature and humidity fluctuations; thus the perturbation in n is a random variable having a spectrum of scales. Although there is a spectrum of spatial scales, only those at about the Bragg wavelength $\Lambda_B = \lambda/[2\sin(\theta_s/2)]$ contribute significantly to the backscattered power. Because scatter is from spatial fluctuations in refractive index, the scattering mechanism is herein defined as Stochastic Bragg Scatter (SBS). Because there are temporal fluctuations as well, the scattered power is also a random variable and its properties are related to the statistical properties of the scattering medium. In this section we relate the expected.....(return to the 3rd sentence in the text)"

459 Eq. (11.124)   this equation assumes that the beam width is given by Eq. (3.2b). A more general form is

$$\rho_\perp = \frac{D_a \sqrt{2}}{\pi \gamma_1}, \qquad \theta_1 = \gamma_1 \frac{\lambda}{D_a}$$

556 at the end of this paragraph, "...in this section.", add: "Under far field conditions the beamwidth part of the "resolution volume weighting" term in Eq.(11.122) does not contribute significantly to the <u>integral</u>, but beamwidth and range resolution do contribute to the backscattered power because they multiply the integral in Eq.(11.122)."

460 0 2 add the following sentence at the end of the line:
ρ_h is the outer scale of the refractive index irregularities, but condition (11.124) applies to the transverse correlation lengths of the Bragg scatterers. Thus, the conclusion reached in this paragraph applies if the Bragg scatterer's correlation length equals the outer scale.

461 0 11 insert after "...in space.": "This is a consequence of the greater importance of the Fresnel term relative to the resolution volume weighting term (i.e., in Eq.11.122) along the transverse directions."

478 0 7 rewrite the sentence: "Then *g*, now the directional gain (section 3.1.2) is related to..."

513 3 4 rewrite as: "...independent of all others because the shell is assumed to be many wavelengths thick and scatterers are randomly placed in the shell.

Some definitions:

Radial: A radial is the center of a band of azimuths over which the radar beam scans during the period (i.e., the dwell time) in which a number M of pulses are transmitted and echoes received and processed. M echo samples at each range are processed to obtain spectral moments (e.g., reflectivity, velocity, and spectrum width) that are assigned to the center azimuth (i.e., the "radial"). A "radial of data" is usually the set of spectral moments at all the range gates (or resolution volumes) along the assigned azimuth.